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[ETD 29: Power Capacitors]

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कैपलिंग कैपीसीटर और कैपीसीटर परकार

(पहला पुनरीक्षण)

Indian Standard

COUPLING CAPACITORS AND CAPACITOR DIVIDERS

(First Revision)

ICS 31.060.70.29.120.30

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

July 1998

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Power Capacitors Sectional Committee, ET 29

NATIONAL FOREWORD

This Indian Standard which is identical with IEC 358 (1990) 'Coupling capacitors and capacitor dividers' issued by the International Electrotechnical Commission was adopted by the Bureau of Indian Standards on the recommendations of the Power Capacitors Sectional Committee (ET 29) and approval of the Electrotechnical Division Council.

The text of the IEC Standard has been approved as suitable for publication as Indian Standard without deviations. This standard supersedes the contents of IS 9348:1979 and constitutes its technical revision.

In the adopted standard, certain terminology and conventions are not identical to those used in Indian Standards. Attention is specially drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standard, the current practice is to use a point (.) as the decimal marker.

In this adopted Standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 50 (436) : 1990 International electrotechnical vocabulary Chapter 436 : Power capacitors	IS 1885 (Part 42) : 1993	Identical
IEC 60-1 : 1989 High voltage test techniques—Part 1 : General definitions and test requirements	IS 207 (Part 1) : 1993	do
IEC 60-2 : 1973 High voltage test techniques—Part 2 : Test procedures	IS 2071 (Part 2) : 1974	Equivalent
IEC 60-3 : 1976, High voltage test techniques—Part 3 : Measuring devices	IS 2071 (Part 3) : 1976	do
IEC 60-4 : 1977, High voltage test techniques—Part 4 : Application guide for measuring devices	IS 8690 : 1977	do
IEC 71-1 : 1976 Insulation coordination—Part 1: Terms, definitions, principles and rules	IS 2165 (Part 1) : 1977	do
IEC 71-2 : 1976 Insulation co-ordinaion—Part 2 : Applicable guide	IS 3716 : 1978	do
IEC 110 : 1973 Recommendations for capacitors for inductive heat generating plants operating at frequencies between 40 and 24 000 Hz	IS 9251 : 1979	do
IEC 143 : 1972 Series capacitors for power systems	IS 9835 : 1981	do
IEC 186 : 1987 Voltage transformers	IS 3156 : 1992	do
IEC 233 : 1974 Tests on hollow insulators for use in electrical equipment	IS 5621 : 1980	do
IEC 252 : 1975 AC Motor capacitors	IS 2993 : 1998	Identical

(*Continued on third cover*)

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Indian Standard

COUPLING CAPACITORS AND CAPACITOR DIVIDERS

(First Revision)

SECTION ONE - GENERAL

Scope

This standard is applicable to:

a) coupling capacitors for power line carrier (PLC) systems on high voltage overhead power lines, the power-frequency range being 15 Hz to 60 Hz, and the carrier frequency range 30 kHz to 500 kHz;

b) capacitor dividers of capacitor voltage transformers. Additional requirements for capacitor voltage transformers are given in IEC Publication 186;

c) capacitors with one terminal either permanently earthed or at low voltage as used for overvoltage protection and other similar uses.

Notes *1.*- Diagrams of capacitors to which this standard applies are given in Figures A1 to A4 in Appendix A.

2.- The following capacitors are excluded from this standard:

- shunt capacitors for a.c. power systems having a rated voltage above 660 V (IEC Publication 871);
- shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 660 V (IEC Publication 831);
- shunt power capacitors of the non self-healing type for a.c. systems having a rated voltage up to and including 660 V (IEC Publication 931);
- capacitors for inductive heat generating plants operating at frequencies between 40 and 24 000 Hz (IEC Publication 110);
- series capacitors (IEC Publication 143);
- capacitors for motor applications and the like (IEC Publication 252);
- capacitors to be used in power electronics circuits (IEC Publication under consideration);

- capacitors for use in tubular fluorescent and other discharge lamp circuits (IEC Publication 566);
- capacitors for suppression of radio interference (IEC Publication 384-14);
- capacitors intended to be used in various types of electrical equipment and therefore considered as components;
- capacitors intended for use with d.c. voltage superimposed on the a.c. voltage.

2. Object

The object of this standard is:

a) to formulate uniform rules regarding performance, testing and rating;

b) to formulate specific safety rules;

c) to provide a guide for installation and operation.

3. Definitions

3.1 *Capacitor element (or element)*

A device consisting essentially of two electrodes separated by a dielectric (IEV 436-01-03*).

3.2 *Capacitor unit (or unit)*

An assembly of one or more capacitor elements in the same container with terminals brought out (IEV 436-01-04).

Notes 1.- A common type of unit for coupling capacitors has a cylindrical housing of insulating material and metal end flanges which serve as terminals.

2.- Units in metal containers usually have one terminal connected to the container and the other brought out through a bushing.

3.3 *Capacitor stack (or stack)*

An assembly of capacitor units connected in series (IEV 436-01-05).

Note.- The capacitor units are usually mounted in a vertical array.

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* IEC Publication 50(436) (in preparation).

3.4 *Capacitor*

A general term used when it is not necessary to state whether reference is made to a capacitor unit or to a capacitor stack.

3.5 *Rated capacitance of a capacitor* (C_N)

The capacitance value for which the capacitor has been designed.

Note.- This definition applies:

- for a capacitor unit, to the capacitance between the terminals of the unit;
- for a capacitor stack, to the capacitance between line and low voltage terminals or between line and earth terminals of the stack;
- for a capacitor divider, to the resultant capacitance:

$$C_1C_2/(C_1 + C_2)$$

3.6 *Rated frequency of a capacitor* (f_N)

The frequency for which the capacitor has been designed (IEV 436-01-14).

3.7 *Rated voltage of a capacitor* (U_N)

The r.m.s. value of the alternating voltage for which the capacitor has been designed (IEV 436-01-15).

3.8 *Rated temperature category of a capacitor*

The range of temperature of the ambient air or of the cooling medium for which the capacitor has been designed (IEV 436-01-17).

3.9 *Capacitor voltage divider*

A capacitor stack forming an alternating voltage divider (IEV 436-02-10).

Notes 1.- See Figures A3 and A4, Appendix A.

2.- A capacitor divider usually forms part of a capacitor voltage transformer.

3.10 *Coupling capacitor*

A capacitor used for the transmission of signals in a power system (IEV 436-02-11).

3.11 *High voltage capacitor (of a capacitor divider)* (C_1)

The capacitor connected between the line terminal and the intermediate voltage terminal of a capacitor divider (IEV 436-02-12).

3.12 *Intermediate voltage capacitor (of a capacitor divider)* (C_2)

The capacitor connected between the intermediate voltage and the low voltage terminals of a capacitor divider (IEV 436-02-13).

3.13 *Line terminal*

A terminal intended for connection to a line conductor of a network (IEV 436-03-01).

3.14 *Earth terminal*

A terminal intended for connection to earth (IEV 436-03-02).

3.15 *Intermediate voltage terminal of a capacitor divider*

A terminal intended for connection to an intermediate circuit, such as the electromagnetic unit of a capacitor voltage transformer (IEV 436-03-03).

3.16 *Low voltage terminal of a capacitor divider*

A terminal intended for connection to earth either directly or via an impedance of negligible value at network frequency (IEV 436-03-04).

Note.- In a coupling capacitor, this terminal is also connected to the carrier frequency coupling device.

3.17 *Capacitance tolerance*

The permissible difference between the actual capacitance and the rated capacitance under specified conditions (IEV 436-04-01).

Note.- The actual capacitance should be measured at, or referred to, the temperature at which the rated capacitance is defined.

3.18 *Equivalent series resistance of a capacitor*

A virtual resistance which, if connected in series with an ideal capacitor of capacitance value equal to that of the capacitor in question, would have a power loss equal to the active power dissipated in that capacitor under specified operating conditions (IEV 436-04-02).

3.19 *High frequency capacitance*

The effective capacitance at a given frequency resulting from the combined effect of the intrinsic capacitance and the self-inductance of a capacitor (IEV 436-04-03).

3.20 *Open-circuit intermediate voltage of a capacitor divider*

The voltage across the terminals of an intermediate voltage capacitor when a voltage is applied between the line and low voltage terminals, no impedance being connected in parallel with the intermediate voltage capacitor (IEV 436-04-04).

3.21 *Ratio of a capacitor divider (voltage ratio)*

The ratio of the voltage applied to the capacitor divider to the open-circuit intermediate voltage (IEV 436-04-05).

Notes 1.- This ratio corresponds to the sum of the capacitances of the high voltage and intermediate voltage capacitors divided by the capacitance of the high voltage capacitor:

$$(C_1 + C_2)/C_1$$

2.- C_1 and C_2 include the stray capacitances, which are generally negligible.

3.22 *Capacitor losses*

The active power dissipated in the capacitor (IEV 436-04-10).

3.23 *Tangent of the loss angle (tan δ)* of a capacitor

The ratio between the equivalent series resistance and the capacitive reactance of a capacitor at specified sinusoidal alternating voltage and frequency (IEV 436-04-11).

3.24 *Highest voltage for equipment* (U_m)

The highest r.m.s. phase-to-phase voltage for which the equipment is designed, in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards.

This voltage shall be equal to or higher than the maximum value of the highest voltage of the system for which the equipment may be used.

3.25 *Rated short-duration power-frequency withstand voltage*

The prescribed r.m.s. value of sinusoidal power-frequency voltage that the equipment shall withstand during tests made under specified conditions and for a duration of 1 min unless otherwise specified.

3.26 *Rated switching (lightning) impulse withstand voltage*

The prescribed peak value of the switching (lightning) impulse withstand voltage which characterizes the insulation of an equipment as regards the withstand tests.

3.27 *Rated insulation level*

a) For capacitors with highest voltage for equipment equal to or greater than 300 kV: the rated switching and lightning impulse withstand voltages.

b) For capacitors with highest voltage for equipment lower than 300 kV: the rated lightning impulse and short-duration power-frequency withstand voltages.

3.28 *Temperature coefficient of capacitance*

The fractional change $1/C_o \quad \Delta C/\Delta t$ of the capacitance for a given change in temperature, where:

ΔC represents the observed change in capacitance over the temperature interval Δt;

C_o represents the capacitance measured at 20 °C.

The temperature coefficient is usually expressed in per cent per kelvin (K).

Note.- The term $\Delta C/C_o$ according to this definition is usable only if the capacitance is an approximately linear function of the temperature in the range under consideration. If not, the temperature dependency of the capacitance should be shown in a graph or a table.

3.29 *Stray capacitance of the low voltage terminal*

The stray capacitance between the low voltage terminal and the earth terminal.

3.30 *Stray conductance of the low voltage terminal*

The conductance between the low-voltage terminal and the earth terminal.

3.31 *Dielectric of a capacitor*

The insulating material between the electrodes.

3.32 *Capacitor voltage transformer*

A voltage transformer comprising a capacitor divider unit and an electromagnetic unit so designed and interconnected that the secondary voltage of the electromagnetic unit is substantially proportional to the primary voltage, and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections (IEV 321-03-14).

3.33 *Carrier frequency coupling device*

An arrangement of circuit devices which contributes to ensuring, through one or more associated coupling capacitors, the transmission under prescribed conditions of carrier frequency signals between one or more conductors of the power-line and the carrier frequency connection.

4. Service conditions

4.1 *Normal service conditions*

This standard gives requirements for capacitors intended for use in the following conditions:

a) Altitude

Not exceeding 1 000 m.

b) Rated temperature categories

Capacitors are classified in temperature categories, each category being specified by one number followed by one letter. The number represents the lowest ambient air temperature and the letter symbolizes the upper limits of the ambient air temperature at which the capacitor may operate continuously with the rated voltage applied.

The temperature categories cover the temperature range -50 °C to +55 °C.

The lowest ambient air temperature should be chosen from the five preferred values: +5 °C, -5 °C, -25 °C, -40 °C, -50 °C. For indoor use, a lower limit of -5 °C is normally applicable.

Table I specifies the relationship between the symbol letter and the upper limits of the ambient air temperature variation ranges.

TABLE I

Symbol	Ambient air temperature (°C)		
	Max.	Highest mean over any period of 24 h	Highest mean over any period of 1 year
A	40	30	20
B	45	35	25
C	50	40	30
D	55	45	35

Any combination of minimum and maximum values can be chosen to define the rated temperature category of a capacitor, e.g. -40/A or -5/C. The preferred rated temperature categories are: -40/A, -25/A, -5/A and -5/C.

Notes *1.-* The temperature values according to Table I can be found in the meteorological temperature tables relating to the installation site, taking into account the remarks of Clause 27.

2.- It is understood that the capacitors are able to withstand frequent switching at temperatures within the range of the rated temperature category.

4.2 *Unusual service conditions*

Unless otherwise agreed between manufacturer and purchaser, this standard does not apply to capacitors, the service conditions of which, in general, are incompatible with the requirements of the present standard.

SECTION TWO - QUALITY REQUIREMENTS AND TESTS

5. **Test requirements**

5.1 *General*

This section specifies the test requirements for capacitors. The electromagnetic unit of a capacitor voltage transformer, instrument transformer, etc., shall be in accordance with the relevant IEC standards.

5.2 *Test conditions*

Unless otherwise specified for a particular test or measurement, the temperature of the capacitor dielectric at the start of the test shall be between +5 °C and +35 °C and shall be known.

It may be assumed that the temperature of the dielectric is the same as that of the ambient air, provided that the capacitor has been left in an unenergized state in a constant ambient-air temperature for an adequate period.

If correction is necessary, the reference temperature shall be +20 °C, unless otherwise agreed between the manufacturer and the purchaser.

Unless otherwise specified the a.c. tests and measurements shall be carried out at a frequency between 0.8 and 1.2 times the rated frequency for capacitors with a rated frequency of 50 Hz or higher and at a frequency between 40 Hz and 72 Hz for capacitors with a rated frequency below 50 Hz.

The type tests shall be carried out on a capacitor stack, unless otherwise specified. The routine tests, if the capacitor consists of several capacitor units, may be carried out on separate units, taking into account the increased test voltage (as specified in Sub-clause 9.1), to cater for the non-uniformity of the voltage distribution due to capacitance tolerance.

6. **Classification of tests**

6.1 *Routine tests*

a) capacitance measurement at power frequency (Clause 7);

b) capacitor loss measurement (Clause 8);

c) a.c. voltage or switching impulse voltage test between terminals (Sub-clause 9.1);

d) a.c. voltage test between low voltage terminal and the earth terminal (Clause 10);

e) partial discharge test (Clause 13 and Sub-clause 13.1);

f) sealing test (Clause 15).

Routine tests shall be carried out by the manufacturer on every capacitor before delivery. At his request, the purchaser shall be supplied with a test report.

The sequence of the tests need not necessarily be the one indicated.

6.2 *Type tests*

a) high frequency capacitance and equivalent series resistance measurements in the range of the rated temperature category (Sub-clause 12.1) (only for capacitors acting as coupling capacitors);

b) stray capacitance and stray conductance measurements of the low voltage terminal (Sub-clause 12.2) (only for capacitors acting as coupling capacitors);

c) a.c. voltage test, dry or wet (Sub-clauses 9.2.1 or 9.2.2);

d) switching impulse voltage test, dry or wet (Sub-clauses 9.2.3 or 9.2.4);

e) lightning impulse voltage test (Sub-clause 9.2.5);

f) discharge test (Clause 11);

g) partial discharge test (Clause 13 and Sub-clause 13.2);

h) determination of the temperature coefficient (Clause 14) (only for capacitor dividers);

k) cantilever test (Clause 16).

Type tests are carried out in order to ascertain that, as regards design, size, materials and performance, the capacitor complies with the specified characteristics and operation requirements specified in this standard. Unless otherwise specified, every capacitor to which it is intended to apply the type test shall first have withstood all routine tests.

The type tests shall be made upon capacitors of a design identical with that of the capacitor under contract or on capacitors of a design and processing that do not differ from it in any way that might influence the properties to be checked by the type test.

It is not essential that all the type tests are carried out on the same capacitor; they may be carried out on different units having the same characteristics.

The type tests shall be carried out by the manufacturer and the purchaser shall, on request, be supplied with a certificate detailing the results of such tests.

6.3 *Acceptance tests*

The routine and/or type tests, or some of them, may be repeated by the manufacturer in connection with any contract by agreement with the purchaser.

The number of capacitors that may be subjected to such repeat tests, and the acceptance criteria, shall be subject to agreement between manufacturer and purchaser, and shall be stated in the contract.

7. Capacitance measurement at power frequency

7.1 *Measuring procedure*

This test may be carried out either on a capacitor stack or on separate units. The capacitance shall be measured using a method that excludes errors due to harmonics and to accessories in the measuring circuit. The accuracy of the measuring method shall be given.

The final capacitance measurement shall be carried out at 0.9 to 1.1 times the rated voltage after the voltage tests (Sub-clause 9.1). In order to reveal any change in capacitance due to the puncture of one or more elements, a preliminary capacitance measurement shall be made before the voltage routine tests, at a sufficiently low voltage (less than 15% of rated voltage) to ensure that no puncture of an element will occur.

Notes *1.-* When there is an intermediate voltage terminal which is still accessible when the capacitor voltage transformer is completely assembled the following should be measured:

a) the capacitance between line and low voltage terminals or line and earth terminals;

b) the capacitance between the intermediate and low-voltage terminals or intermediate voltage and earth terminals.

2.- If the dielectric system of the capacitor is such that the measured capacitance varies with the voltage, it is more meaningful to repeat the capacitance measurement after the voltage test at the same voltage as that previously used and then at the measuring voltage of 0.9 to 1.1 times the rated voltage.

3.- If the number of elements in series in the tested unit is large, it may be difficult to ascertain that no puncture has occurred because of the following uncertainties:

- reproductibility of the measurement;
- capacitance change caused by the mechanical forces on the elements during the voltage tests;

- capacitance change caused by temperature difference of the capacitor before and after the tests.

In this case, it should be proved by the manufacturer, for example by comparing the capacitance variations of capacitors of the same type and/or by calculation of the capacitance change caused by the temperature increase during the test, that no puncture had occurred. In view of the uncertainty in the case where measurements are made on a stack, it may be preferable to carry out these measurements on each unit separately.

4.- Measurement of the capacitance may be made at a frequency outside the range specified in Sub-clause 5.2, provided an appropriate correction factor is agreed.

7.2 *Capacitance tolerances*

The measured capacitance shall not differ from the rated capacitance by more than -5% to +10%.

The ratio of the capacitances of any two units forming part of a capacitor stack shall not differ by more than 5% from the reciprocal ratio of the rated voltages of the units.

Note.- In the case of capacitor dividers, close tolerances on the voltage ratio may be required by the manufacturer of the capacitor voltage transformer; these values should be settled by agreement for each particular case.

8. Capacitor loss measurement

8.1 *Measuring procedure*

The capacitor losses (tan δ) shall be measured at 0.9 to 1.1 times the rated voltage after the voltage tests, using a method that excludes errors due to harmonics and to accessories in the measuring circuit. The accuracy of the measuring method shall be given.

8.2 *Loss requirements*

The requirements relating to capacitor losses may be agreed upon between manufacturer and purchaser.

Notes 1.- The purpose of the measurement of the losses is to check the uniformity of the production.

2.- The tan δ value depends on the type of dielectric.

3.- The tan δ value of certain types of dielectric is a function of the energization time before the measurement.

4.- Measurement of the losses may be made at a frequency outside the range specified in Sub-clause 5.2, provided an appropriate correction factor is agreed upon.

9. Voltage tests

9.1 *Routine test*

Every capacitor stack with U_m < 300 kV shall be subjected to test *a)* and every capacitor stack with U_m ≥ 300 kV to test *a)* or *b)*, the test voltage being applied between the line and the earth terminals when testing a capacitor stack, and between the terminals when testing a unit. When a low voltage terminal is provided, it shall be connected directly, or by a low impedance, to earth during this test. In the absence of any agreement, the choice between tests *a)* or *b)* is left to the manufacturer. During the test, neither puncture (see Sub-clause 7.1) nor flashover shall occur.

When testing a single unit forming part of a stack, the value of the test voltage shall be equal to:

$$1.05 \times \text{test voltage of the stack} \times \frac{\text{rated voltage of the unit}}{\text{rated voltage of the stack}}$$

a) An a.c. test, the test voltage being:

- for capacitor stacks with U_m < 300 kV: the rated short-duration power-frequency withstand voltage, given in Column 3 of Table III and corresponding to the highest voltage for equipment of the capacitor;

- for capacitor stacks with U_m ≥ 300 kV: the equivalent rated short duration power-frequency withstand voltage, given in Column 4 of Table IV and corresponding to the highest voltage for equipment of the capacitor.

The test shall be carried out with a substantially sinusoidal waveshape in accordance with IEC Publication 60. The voltage shall be rapidly increased from a relatively low value to the test voltage value, maintained for 1 min, unless otherwise agreed, and then rapidly reduced to a relatively low value before being switched off.

b) An a.c. test with three superimposed switching impulses of positive or negative polarity, the peak value of the test voltage being the rated switching impulse withstand voltage, given in Column 2 of Table IV and corresponding to the highest voltage for equipment of the capacitor. This switching impulse test shall be combined with the partial discharge test, which shall be however performed in accordance with procedure *b)* of Sub-clause 13.2, the measuring time being reduced from 1 h to 1 min.

Notes *1.-* For the switching impulse test; the wavefront may differ from the standard switching impulse according to IEC Publication 60. The time-to-half value shall however be at least 2 500 µs.

2.- For capacitors (coupling capacitors or capacitors used only for overvoltage protection) having such a high capacitance value that the characteristics of the testing equipment do not permit the a.c. test (overloading of the test equipment) to be performed, a d.c. test may be agreed upon between manufacturer and purchaser at the request of the manufacturer. The test procedure shall be the same as for test *a)* above, the test voltage being twice the r.m.s. value of the a.c. test voltage.

9.2 *Type test*

9.2.1 *A.C. voltage test, dry (for indoor capacitors with U_m < 300 kV)*

The test shall be carried out on a capacitor stack.

An a.c. test voltage equal to the rated short duration power-frequency withstand voltage, given in Column 3 of Table III and corresponding to the highest voltage for equipment of the capacitor shall be applied between the line and earth terminals. When a low voltage terminal is provided it shall be connected directly, or via a low impedance, to earth during this test.

The test shall be carried out with a substantially sinusoidal wave-shape in accordance with IEC Publication 60. The voltage shall be rapidly increased from a relatively low value to the test voltage value, maintained for 1 min and rapidly reduced to a relatively low value before being switched off.

No flashover or puncture shall occur. To ensure that no puncture has occurred, a measurement of the capacitance of the units at 0.9 to 1.1 times the rated voltage shall be made before and after the test (see Note 3 of Sub-clause 7.1).

9.2.2 *A.C. voltage test, wet (for outdoor capacitors with U_m < 300 kV)*

The test conditions are as specified in Sub-clause 9.2.1, but under artificial rain in accordance with IEC Publication 60.

9.2.3 *Switching impulse voltage test, dry (for indoor capacitors with $U_m \geq$ 300 kV)*

The test shall be carried out on a capacitor stack.

Fifteen switching impulses of each polarity, with a peak value equal to the rated switching impulse withstand voltage, specified in Column 2 of Table IV and corresponding to the highest voltage for equipment of the capacitor, shall be applied between the line and earth terminals. When a low voltage terminal is provided, it shall be connected directly, or via a low impedance, to earth during this test.

The waveform of the applied impulses shall be the standard wave 250/2 500 µs in accordance with IEC Publication 60.

The capacitor stack may be mounted on a metal pedestal having a height of not more than 2.5 m and an equivalent diameter of at least two times the largest diameter of the insulating envelope of the capacitor.

No grading screen, etc., shall be mounted on the stack other than those belonging to it when connected in service.

If not more than two flashovers occur on either polarity, the capacitor stack shall be deemed as having passed the test.

No internal puncture shall occur, which shall be verified by means of oscillograph records of the impulse voltage wave and by a measurement of the capacitance of the units at 0.9 to 1.1 times the rated voltage before and after the test (see Note 3 of Sub-clause 7.1).

Notes *1.-* If documentation is available, showing that the insulating housing can withstand fifteen switching impulses of each polarity with not more than two flashovers on either polarity, the test can be performed with only three impulses of each polarity. In this case, no flashover and no puncture should occur. For statistical reasons however, a repetition of the test with three impulses is allowed if one flashover only has occurred.

2.- Mounting of the capacitor stack on a metal pedestal influences the switching impulse withstand characteristics. It is therefore acceptable to perform the test with a pedestal mounting corresponding to the service conditions. It should be noted that direct positioning on an earthed floor is the most severe case.

3.- The arrangement of the line connection can influence the flashover characteristics. It may therefore be necessary to perform the type test with a line connection corresponding to service conditions at the option of the manufacturer.

4.- Two different but identical stacks may be used, one for each polarity.

9.2.4 *Switching impulse test, wet (for outdoor capacitors with $U_m \geq 300$ kV)*

The test conditions are as specified in Sub-clause 9.2.3, but the test shall be carried out under artificial rain in accordance with IEC Publication 60.

9.2.5 *Lightning impulse voltage test*

The test shall be carried out on a capacitor stack.

Fifteen lightning impulses of each polarity, with a peak value equal to the rated lightning impulse withstand voltage, given in Column 2 of Table III, or Column 3 of Table IV and corresponding to the highest voltage for the equipment of the capacitor, shall be applied between the line and earth terminals. When a low voltage terminal is provided, it shall be connected directly, or via a low impedance, to earth during this test.

The waveform of the applied impulses shall be in accordance with IEC Publication 60, but the front time may be increased to a maximum of 8 µs at the request of the manufacturer, owing to the limitations of the testing equipment.

If not more than two flashovers occur on either polarity, the capacitor stack shall be deemed as having passed the test.

No internal puncture shall occur, which shall be verified by oscillograph records of the impulse voltage wave and a measurement of the capacitance of the units at 0.9 to 1.1 times the rated voltage before and after the test (see Note 3 of Sub-clause 7.1).

Notes 1.- If documentation is available, showing that the insulating housing can withstand fifteen lightning impulses of each polarity with not more than two flashovers on either polarity, the test can be performed with only three impulses of each polarity. In this case, no flashover and no puncture should occur. For statistical reasons, however, a repetition of the test with three impulses is allowed if one flashover only has occurred.

2.- Two different but identical stacks may be used, one for each polarity.

3.- For capacitors with $U_m < 300$ kV, a test with positive polarity only may be agreed between manufacturer and purchaser.

10. Voltage test between low voltage terminal and earth terminal

Capacitors with a low voltage terminal shall be subjected for 1 min to an a.c. test between the low voltage and earth terminals.

a) If the low voltage terminal is exposed to the weather, the test voltage shall be 10 kV r.m.s.

b) If the low voltage terminal is not exposed to the weather, for instance when inside the terminal box of a capacitor voltage transformer, the test voltage shall be 4 kV r.m.s.

During the test, neither puncture nor flashover shall occur.

Note.- If the test voltage is too low for the insulation co-ordination of the carrier accessories with the low voltage terminal, a higher value may be agreed upon at the request of the purchaser.

11. Discharge test

The test may be carried out either on a capacitor stack or on a unit. A voltage shall be applied between the line and earth terminals of a stack or between the terminals of a unit in order to charge the capacitor to a voltage equal to the rated lightning impulse withstand voltage, specified in Column 2 of Table III, or in Column 3 of Table IV, and corresponding to the highest voltage for equipment of the capacitor. The capacitor shall then be discharged through a rod gap so situated as to obtain a discharge frequency between 0.5 and 1 MHz.

When a low voltage terminal is provided, it shall be connected directly, or via a low impedance, to earth during this test.

The test shall be made twice within 5 min. The absence of failure shall be verified by measurement of the capacitance of the unit(s) at 0.9 to 1.1 times the rated voltage before and after the test (see Note 3 of Sub-clause 7.1).

Notes 1.- In the case of capacitors having large dimensions, high voltage and/or high capacitance as used for example for overvoltage protection, a lower discharge frequency might occur.

2.- This test is intended to check the internal connections of the capacitor.

3.- The capacitor may be charged either by means of a d.c. generator or by an impulse generator, the choice being left to the manufacturer.

12. High frequency measurements (only for coupling capacitors and capacitor dividers intended for carrier coupling)

12.1 *High frequency capacitance and equivalent series resistance*

The measurements shall be carried out on a capacitor stack.

The capacitances and the equivalent series resistances shall be measured at the two temperatures equal to the limits of the temperature category and at a temperature within the standard range for testing (Sub-clause 5.2), at several frequencies over the whole frequency range specified in Clause 1.

The measured values of the capacitance between the line and low-voltage terminals shall not deviate by more than -20% to +50% from the rated capacitance. The measured values of the equivalent series resistance between the same terminals shall not exceed 40 Ω at any frequency and temperature.

For the lower measuring frequencies (for instance 30 kHz to 100 kHz) with a temperature equal to the lower limit of the category, or for capacitor stacks with a capacitance equal to or less than 2 000 pF, or for U_m greater than 420 kV, the equivalent series resistance may be higher than 40 Ω. In this case, the value shall be agreed between manufacturer and purchaser.

For high frequency characteristics and measuring methods, see Appendix B.

Note.- In the case of practical difficulties in carrying out the measurements at the limits of the temperature category, the purchaser and the manufacturer may agree on measurements over a smaller temperature range, or on measurements performed on a model capacitor containing a limited number of elements.

12.2 *Measurement of the stray capacitance and stray conductance of the low voltage terminal*

The measurements shall be carried out either on a unit or on a model representative of the bottom part of the capacitor under consideration.

This model shall include the earth terminal, the metal parts (e.g. flanges) permanently connected to it, and the low voltage terminal with at least one element connected to it and placed in its proper position. If a model is used, it shall be filled with the insulating liquid used for the capacitor.

The values of the stray capacitance and the stray conductance, measured at any frequency in the carrier frequency range, shall not exceed 200 pF and 20 µs respectively.

For a capacitor voltage transformer, the measurements shall be carried out on the complete capacitor voltage transformer or on the lowest unit of the capacitor divider with connected electromagnetic unit. In this case, higher values of the stray capacitance and the stray conductance may be agreed upon between manufacturer and purchaser.

The requirements are further dealt with in Appendix B.

Note.- To avoid a harmful increase of the stray conductance in polluted ambient conditions, the low voltage terminal should have a creepage distance in accordance with Clause 18.

13. Partial discharge test

The test circuit for the measurement of partial discharges shall be in accordance with Sub-clause 4.2 of IEC Publication 270.

The measuring instrument used shall comply with Sub-clause 4.3 of IEC Publication 270.

The instrument used will depend on the quantity to be measured; the quantity preferred in this standard is the apparent charge *q* expressed in picocoulombs (pC). The characteristics of the test circuit shall be such that a minimum discharge intensity of 5 pC is measurable.

The calibration of the measuring circuit shall be performed according to Clause 5 of IEC Publication 270.

The test shall be carried out either on a capacitor stack or on a separate unit, taking into account the formula for the test voltage given in Sub-clause 9.1.

Notes *1.-* The test circuit should be arranged so that the measurement of the partial discharge intensity is not affected by external corona discharges.

2.- Wideband measurement of partial discharges with a bandwidth of at least 100 kHz offers certain advantages especially where test objects with distributed capacity and inductance are concerned. Normally, however, a narrow band measurement of partial discharges is sufficient for coupling capacitors, particularly if there is a possibility of choosing between measuring frequencies in the range 0.15 MHz to 2 MHz. Preferred values are 0.5 MHz and 1 MHz, but, if feasible, the measurement should be performed at the frequency which gives the highest sensitivity.

3.- The measurement of the magnitude of partial discharges may be insensitive if the capacitance of the unit to be tested is too large in relation to that for which the test apparatus has adequate sensitivity. In this case, an agreement should be reached between the manufacturer and purchaser to carry out the test on a model unit having a smaller voltage and/or capacitance rating but of the same design and construction as that supplied.

4.- When using instrumentation which gives the discharge intensity in units other than picocoulombs, IEC Publication 270 should be consulted.

13.1 *Routine test*

The partial discharge routine test shall be made after the voltage test between terminals described in Sub-clause 9.1 but before the final capacitance measurement described in Sub-clause 7.1.

An a.c. voltage shall be applied between the line and earth terminals of a stack or between the terminals of a unit and rapidly increased from a relatively low value to the pre-stress voltage (values given in Table II), maintained for at least 10 s, rapidly reduced to the partial discharge measuring voltage also given in Table II, and the partial discharge intensity shall be measured after at least 1 min. Preferred values for the permissible levels of partial discharge intensity are given in Table II.

The voltage applied during this test shall be of substantially sinusoidal wave shape in accordance with Publication 60. The test circuit shall be suitably damped to reduce, as much as possible, overvoltages due to transients.

Note.- Alternatively, the partial discharge test may be performed while decreasing the voltage after the power frequency withstand voltage test of Sub-clause 9.1. If the measured partial discharge values exceed the permitted limits of Table II, a separate test as specified above may be carried out.

TABLE II

Type of earthing 1)	Pre-stress voltage ≥ 10 s 2)	Measuring voltage ≥ 1 min 2)	Permissible partial discharge level 2)
			Apparent charge
Networks with an isolated or resonant earthed starpoint	$1.3\ U_m$	$1.1\ U_m$ 3)	100 pC 3)
		$1.1\ U_m/\sqrt{3}$	10 pC
Networks with an effectively earthed starpoint	$0.8 \times 1.3\ U_m$	$1.1\ U_m/\sqrt{3}$	10 pC

1) If there is no clear distinction to be made for which kind of network (starpoint either isolated or effectively earthed) the capacitor is meant, the levels for an isolated starpoint shall be taken.

2) These values are found by experience to guarantee reasonably reliable products at reasonable cost. Whenever it is possible to clearly distinguish between higher background disturbances and the partial discharges arising from the test object, these higher disturbances may be acceptable if agreed by manufacturer and purchaser.

3) These values apply only if agreed upon between manufacturer and purchaser.

[4] For capacitors having very large rated capacitance, a partial discharge test with the values specified above may be impossible to carry out because of the poor transmission factor and the power limitation of the test transformer. In such cases, the relevant values should be agreed upon between manufacturer and purchaser.

13.2 *Type test*

The partial discharge type test shall be carried out in accordance with procedure *a)* for capacitor stacks with U_m < 300 kV and in accordance with procedure *a)* or *b)* for capacitor stacks with $U_m \geq 300$ kV. The use of procedure *b)* shall only be made by agreement between manufacturer and purchaser.

- Procedure *a)*

  An a.c. voltage shall be applied between the line and earth terminals of a stack or between the terminals of a unit and rapidly increased from a relatively low value to the pre-stress voltage values specified in Table II, maintained for at least 10 s, rapidly reduced to the partial discharge measuring voltage also specified in Table II and maintained for 1 h. During this period the partial discharge intensity shall be measured approximately every 10 min.

- Procedure *b)*

  An a.c. voltage shall be applied between the line and earth terminals of a stack or between the terminals of a unit, and rapidly increased from a relatively low value to 1.5 $U_m/\sqrt{3}$ (r.m.s). At the beginning of the test, at least three switching impulses shall be superposed on the mentioned voltage in order to obtain a peak value of the resulting voltage equal to the rated switching impulse withstand voltage given in Column 2 of Table IV, and corresponding to the highest voltage for equipment of the capacitor.

The a.c. voltage shall be maintained at 1.5 $U_m/\sqrt{3}$ for 1 h. During this period, the partial discharge intensity shall be measured approximately every 10 min.

The wavefront of the switching impulse superposed on the a.c. voltage may differ from the standard switching impulse in accordance with IEC Publication 60. The time-to-half value shall, however, have a value of at least 2 500 μs.

Note.- If the capacitors are used in networks with non-effectively earthed starpoint, another value of the a.c. voltage may be agreed upon between the manufacturer and purchaser.

Preferred values for the permissible levels of partial discharge intensity are specified in Table II.

Except for the switching impulse superposed on the a.c. voltage, the test and measuring voltages applied during this test shall have a substantially sinusoidal waveshape in accordance with IEC Publication 60. The test circuit shall be suitably damped to reduce, as much as possible, overvoltage due to transients.

Note.- This test should be made in accordance with the above test cycles, without interruption of the voltage.

14. Determination of the temperature coefficient

This test applies only to capacitor dividers and need only be carried out if agreed between purchaser and manufacturer.

The test may be carried out on a capacitor unit or on a model capacitor composed of the same elements and having the same clamping construction as the capacitor under consideration. The test capacitor shall be placed in an enclosure in which the air temperature can be adjusted to any value between the lower limit of the temperature category and 15 K in excess of the upper limit of the temperature category. Alternatively, a liquid bath which can be adjusted within the same temperature limits may be used.

The value of the capacitance (and, for information, the tangent of the loss angle) shall be measured at reduced voltage (but not less than 0.25 U_N) and frequency within the range specified in Sub-clause 5.2 at temperature intervals of approximately 15 K. Before each measurement, the thermal equilibrium of the capacitor shall be established.

The temperature coefficient derived from these measurements shall not exceed either the value specified by the purchaser or, in the absence of a specified value, the value guaranteed by the manufacturer.

The voltage shall be applied to the capacitor only for the period of time necessary for taking the measurement.

Notes 1.- If a model capacitor is used for this test, the number of elements employed should be sufficiently large to ensure that, together with their clamping devices, they constitute a model which is truly representative, both mechanically and electrically, of the capacitor under consideration.

2.- If the manufacturer can provide a test certificate of an earlier test covering the whole of the temperature range mentioned in this clause, a repetition of the test over a smaller temperature range may be agreed upon.

3.- The change in the voltage ratio of the capacitor divider with temperature, which normally is of greater importance for the accuracy of a capacitor voltage divider than the variation of the equivalent capacitance, cannot be derived from this test because the temperature variations in the stack due to operating temperature rises in the units are not taken into account (see Clause 53 of IEC Publication 186).

15. Sealing test

If no agreement has been made, the sealing of the capacitor shall be tested by a method left to the choice of the manufacturer. The test may be performed at any time after the completion of the capacitor.

16. Cantilever test

A test force F_T shall be applied to the top terminal of the capacitor perpendicular to its axis and in the least favourable direction for a duration of 1 min.

The test force F_T depends on the capacitor dimensions, length l and largest shed diameter d of the insulating envelope and shall be calculated as follows:

$$F_T = [(450 \times l \times d) + 500] \times 1.5 \quad (N)$$

where l and d are in metres.

The capacitor has successfully passed the test if there is no rupture and no evidence of leakage. Absorbent paper, white chalk or an equivalent method shall be used to indicate any resultant leakage.

Notes *1.-* The coefficients of the above equation for the test force F_T are based on a maximum wind velocity of 150 km/h (in accordance with Clause 29), giving an equivalent wind pressure of 900 N/m², for a maximum lateral line force at the top of the capacitor of 500 N and for a safety factor of 1.5.

2.- If a capacitor is equipped with a lateral intermediate or low-voltage terminal which pierces the cylindrical wall of the porcelain housing, the test force shall be applied both in a direction parallel to this terminal and normal to it.

SECTION THREE - INSULATION LEVELS AND CREEPAGE DISTANCE

17. Insulation levels and test voltages

Tables III and IV specify the standard insulation levels with the corresponding highest voltage for equipment U_m (r.m.s). The insulation level is defined by the r.m.s. value of the rated power-frequency short-duration withstand voltage and the peak value of the rated lightning impulse withstand voltage for $U_m < 300$ kV and by the peak values of the rated switching and lightning impulse withstand voltages for $U_m \geq 300$ kV.

Notes *1.-* For values of U_m below 12 kV, the insulation level should be chosen from the tables in IEC Publication 71.

2.- Guidance for the choice of the insulation level is given in Clause 26.

3.- The insulation levels and test voltages may differ from those stated in Tables III and IV according to national standards and if agreed between manufacturer and purchaser.

TABLE III

Standard insulation levels for $12\ \text{kV} \leq U_m < 300\ \text{kV}$

1	2	3
Highest voltage for equipment U_m (r.m.s.)	Rated lightning impulse withstand voltage (peak)	Rated short-duration power-frequency withstand voltage (r.m.s)
kV	kV	kV
12	60	28
	75	28
24	95	50
	125	50
36	145	70
	170	70
52	250	95
72.5	325	140
123	450	185
	550	230
145	(450	185)
	550	230
	650	275
170	(550	230)
	650	275
	750	325
245	(650	275)
	(750	325)
	850	360
	950	395
	1 050	460

Notes *1.-* The choice of the insulation level shall be made in accordance with Clause 26 and with IEC Publication 71.

2.- Non-preferred values are given in brackets.

TABLE IV

Standard insulation levels for $U_m \geq 300$ kV

1	2	3	4
Highest voltage for equipment U_m (r.m.s)	Rated switching impulse withstand voltage (peak)	Rated lightning impulse withstand voltage (peak)	Equivalent rated short-duration power-frequency withstand voltage (r.m.s)
kV	kV	kV	kV
300	(750	850	395)
	750	950	395
	(850	950	460)
	850	1 050	460
362	(850	950	460)
	850	1 050	460
	(950	1 050	510)
	950	1 175	510
420	(950	1 050	510)
	950	1 175	510
	(1 050	1 175	570)
	1 050	1 300	570
	1 050	1 425	630
525	(1 050	1 175	570)
	(1 050	1 300	570)
	1 050	1 425	630
	(1 175	1 300	630)
	(1 175	1 425	630)
	1 175	1 550	680
765	(1 300	1 425	680)
	(1 300	1 550	680)
	1 300	1 800	790
	(1 425	1 550	790)
	(1 425	1 800	790)
	1 425	2 100	880
	(1 550	1 800	880)
	(1 550	1 950	880)
	1 550	2 400	975

Notes 1.- The choice of the insulation level shall be made in accordance with Clause 26 and with IEC Publication 71.

2.- Non-preferred values are given in brackets.

3.- Column 4 specifies values which are not given in Publication 71. These values are given in order to permit an a.c. routine voltage test (see Sub-clause 9.1).

18. Creepage distance

For outdoor insulation susceptible to contamination, the required minimum rated creepage distance measured on the insulation surface shall comply with the following values (in millimetres per unit of the highest voltage for equipment U_m):

- for light pollution level	16 mm/kV
- for medium pollution level	20 mm/kV
- for heavy pollution level	25 mm/kV
- for very heavy pollution level	31 mm/kV

In addition, the ratio of the rated creepage distance to the arcing distance should generally not exceed 3.5/1.

The value of the creepage distance in the rain shadow at an angle of precipitation of 90° to the axis of the insulating envelope should generally not exceed 50% of the total creepage distance.

Low-voltage terminals exposed to the weather shall have a rated creepage distance of at least 60 mm.

Notes *1.-* The actual value of the creepage distance can differ from the rated value by the manufacturing tolerances stated in Clause 7 of IEC Publication 233.

2.- The definition for the various pollution classes is still under consideration.

3.- The above values of the specific rated creepage distance are provisional. The values are in accordance with IEC Publication 815.

4.- Artificial pollution tests are not included in this standard. They are described in IEC Publication 507. More experience is needed before a test method based on this report can be issued.

5.- It is recognized that the performance of the surface insulation is greatly affected by the insulator shape. Also other measures, such as periodical cleaning of the insulator surface with water or greasing the surface, can improve the performance of the insulating enclosure under pollution.

SECTION FOUR - SAFETY REQUIREMENTS

19. Connections to metal parts

It shall be possible to make reliable connections to any metal parts or terminals of the capacitor to enable the potential of these metal parts to be fixed. Metal parts which are at earth potential in normal service shall be connected to earth.

20. Protection of the environment

When capacitors are impregnated with products that shall not be dispersed into the environment, precautions shall be taken. In some countries, there are legal requirements in this respect.

21. National regulations

The purchaser shall specify, at the time of ordering, any special requirements relating to safety regulations which apply to the country in which the capacitor is to be installed.

SECTION FIVE - MARKINGS

22. Marking of the capacitor unit

22.1 *Rating plate*

The following information shall be given on the rating plate of each capacitor unit:

1) Manufacturer.
2) Identification number and year of manufacture.
   The year may be a part of the identification number or be in code form.
3) Measured capacitance, C_N, in picofarads.
4) Rated voltage, U_N, in kilovolts.

22.2 *Warning plate*

If the capacitor unit contains material that might pollute the environment or may be hazardous in any other way, the unit shall be equipped with a label according to the relevant laws of the country of the user, who shall inform the manufacturer about such laws.

23. Marking of the capacitor stack

23.1 *Rating plate*

The following information shall be given on the rating plate of each capacitor stack:

1) Manufacturer.
2) Identification number and year of manufacture.
   The year may be a part of the identification number or be in code form.
3) Rated capacitance, C_N, in picofarads.
4) Rated voltage, $U_m/\sqrt{3}$ or U_m, in kilovolts.
5) Rated frequency, f_N, in hertz.

6) Temperature category.
7) Diagram, showing the terminal markings (if necessary).
8) Insulation level (see Note 1).
9) Mass, in kilograms.
10) Reference to IEC Publication 358 (with year of issue).

Notes 1.- The insulation level should be given by means of two numbers separated by a stroke, the first number giving the r.m.s. value of the rated short-duration power-frequency withstand voltage (for $U_m < 300$ kV) or the peak value of the rated switching impulse withstand voltage (for $U_m \geq 300$ kV), in kilovolts, and the second number giving the peak value of the rated lightning impulse withstand voltage, in kilovolts (for example (460/1 050 or 1 050/1 425).

2.- It is useful to give values of test measurements in a test report.

23.2 *Rating plate of capacitor divider*

In addition to points 1) to 10) of Sub-clause 23.1, the following information shall be given on the rating plate of each capacitor stack only in the cases where an intermediate voltage terminal is still accessible when the capacitor voltage transformer is completely assembled:

11) Measured voltage ratio.

23.3 *Warning plate*

Sub-clause 22.2 is also valid for the capacitor stack.

SECTION SIX - GUIDE FOR INSTALLATION AND OPERATION

24. General

Unlike most electric apparatus, capacitors, whenever energized, operate continously at full load or at loads that deviate from this value only as a result of voltage and frequency variations.

Overstressing and overheating shorten the life of a capacitor and therefore the operating conditions (i.e. temperature, voltage and current) should be strictly controlled.

Because of the different types of capacitors and the many factors involved, it is not possible to cover by simple rules the installation and operation in all possible cases. The following information covers the most important points to be considered.

In addition, the instructions of the manufacturer and of the power supply authorities should be followed.

25. Choice of rated voltage

In three-phase systems, the rated voltage U_N of a capacitor should, as a general rule, be chosen equal to $U_m/\sqrt{3}$. If a capacitor stack is composed of several units, the rated voltage of each unit should be at least that value of the voltage which appears across the unit when the rated voltage is applied to the stack, assuming that both the stack and the units have the rated capacitance. This value of the voltage or a higher value should be shown on the rating plate of the unit.

Note.- Owing to the capacitance tolerances allowed in Sub-clause 7.2, the test voltage, when testing separate units, has been chosen 5% in excess of the voltage calculated on the assumption of zero capacitance tolerances.

26. Choice of insulation level

Tables III and IV show the recommended combinations of the standard insulation levels. In general, the value to be recommended for the insulation level is governed by two main factors:

a) the earth fault factor;

b) the protection level of the protective equipment.

In the case of systems without suitable overvoltage protection, the upper limit of overvoltage which can occur at the line terminals of the capacitors cannot be determined accurately, even though the presence of the capacitor may reduce the magnitude of transient overvoltages of very short duration to some extent. Therefore, in the absence of suitable overvoltage protection, the highest insulation level shown in Tables III and IV for a given value of U_m should be chosen, but nevertheless, damage may still occur under very unfavourable conditions.

If overvoltage protection is provided close to the capacitor, the crest value of the rated switching and lightning impulse withstand voltages should be matched to the protection level of the protective equipment (see IEC Publications 71-1 and 71-2, especially Section Three and Appendix A).

27. Operating temperature

27.1 *General*

Particular attention should be paid to the operating temperature of the capacitor because this has a great influence on its life.

27.2 *Choice of the temperature category (Sub-clause 4.1)*

The lower limit of the temperature category should obviously be chosen in accordance with the lowest ambient air temperature expected at the proposed location of the capacitor.

When selecting the upper limit of the temperature category, the possible increase in temperature by radiation from the sun should be taken into account. Capacitors in outdoor positions are generally not protected from radiation from the sun. If they are composed of units with dark-coloured housings (either ceramic or metal), an extra margin should be allowed when selecting the upper limit of the temperature category if frequent exposure to intense solar radiation is expected. Temperature categories of symbol B or C may be required, even though the ambient air temperature might not call for such high figures.

27.3 *Tropical conditions*

Capacitors for symbol C are suitable for the majority of applications under tropical conditions. In some locations, however, the ambient temperature may be such that a capacitor of symbol D is required. The latter may also be needed for those cases where the capacitors are frequently subjected to the radiation of the sun for several hours (e.g. in desert territories), even though the ambient temperature is not excessive (Sub-clause 27.2).

In exceptional cases, the ambient temperature may be higher than 55 °C maximum, or 45 °C daily average, and capacitors of special design or with a higher rated voltage shall be used.

27.4 *Network in which a sustained earth fault can occur*

A special case may arise when capacitors are used in a network in which a sustained earth fault can occur for a considerable time, for instance up to eight consecutive hours, which may be the case in some networks with an isolated or resonant earthed starpoint. IEC Publication 186 specifies for voltage transformers (including capacitor voltage transformers), used between line and earth in such networks, a test with 1.9 times the rated voltage for 8 h. This requirement increases the temperature rise of the capacitor, as its losses are 3.6 times as high as at rated voltages and the problem of thermal stability may arise. For this special case, the manufacturer should be consulted in order to decide on the possible necessity of decreasing the electric stress at rated voltage, which in fact is equivalent to increasing the highest voltage for equipment. In case of doubt, a test simulating the conditions under prolonged earth fault operation should be agreed upon.

28. Special conditions

Apart from high ambient temperature, other adverse conditions of use are liable to be encountered in tropical countries. If the purchaser is aware of such conditions the manufacturer should be informed when the capacitors are ordered. This information should also be given to the suppliers of all associated equipment for the capacitor installation.

The most important conditions are the following:

a) *Frequent occurrence of periods of high relative humidity*

It may be necessary to use insulators of special design.

b) *Rapid mould growth*

Mould growth does not develop on metals, ceramic materials and certain kinds of paints and lacquers. For other materials, mould growth may develop on humid places, especially where dust, etc., can settle. The use of fungicidal products may improve the behaviour of these materials.

c) *Corrosive atmosphere of industrial and coastal areas*

It should be noted that in climates with higher temperatures the effects of such atmospheres may be more severe than in temperate climates. A highly corrosive atmosphere may be present also for indoor application.

d) *Pollution*

When capacitors are to be installed at a location where the pollution is considerable, special precautions should be taken.

e) *Altitude exceeding 1 000 m*

Capacitors used at altitudes exceeding 1 000 m are subjected to special conditions owing to the fact that the flashover of external insulation depends upon the prevailing atmospheric conditions. To ensure that the withstand voltages of the external insulation of a capacitor, intended for operation at altitudes exceeding 1 000 m above sea level, are sufficient, the arcing distance normally has to be increased.

For general guidance, the withstand voltage, on which the arcing distance is based, should be increased by 1% for each 100 m in excess of 1 000 m above sea level.

29. Mechanical stress

Capacitors intended for outdoor mounting should withstand the mechanical stresses resulting from winds of 150 km/h. In the case of more stringent conditions, such as higher winds, ice formation, mounting of line traps on the capacitor, or the possibility of earthquakes, the purchaser should inform the manufacturer so that measures can be taken to ensure adequate strength of the capacitor. When line traps are to be fitted, this information should also include: probable stresses resulting from short-circuit currents depending on the layout of the substation, type and design of the line trap intended to be mounted on the capacitor, etc.

Capacitors should be connected to the line conductors in such a way that the capacitor is not subjected to a lateral force exceeding 500 N (see Clause 16, Note 1).

APPENDIX A

CAPACITOR DIAGRAMS

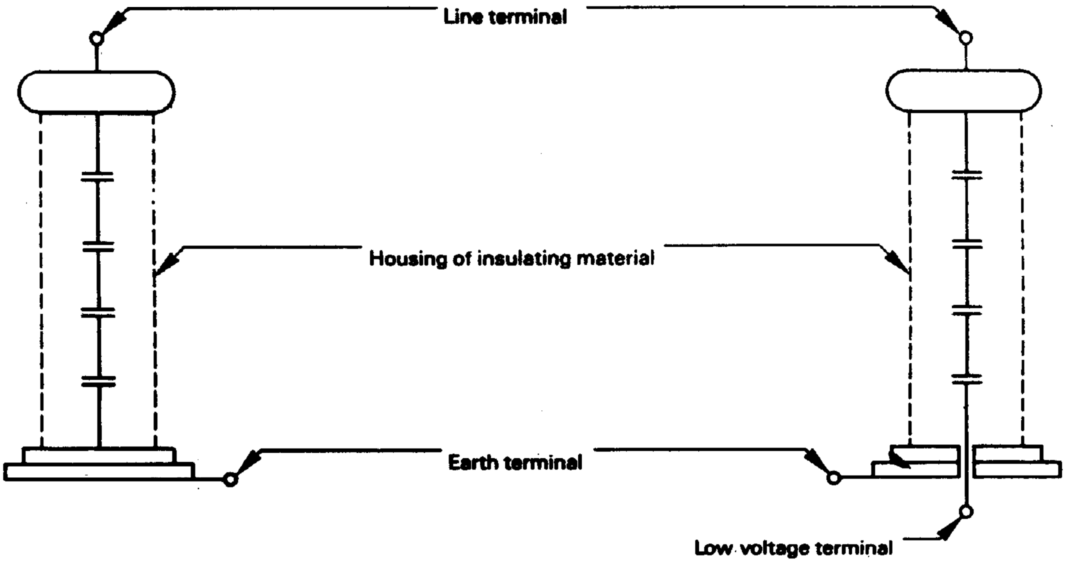


FIG. A1. - Capacitor for overvoltage protection.

FIG. A2. - Capacitor for power line carrier coupling.

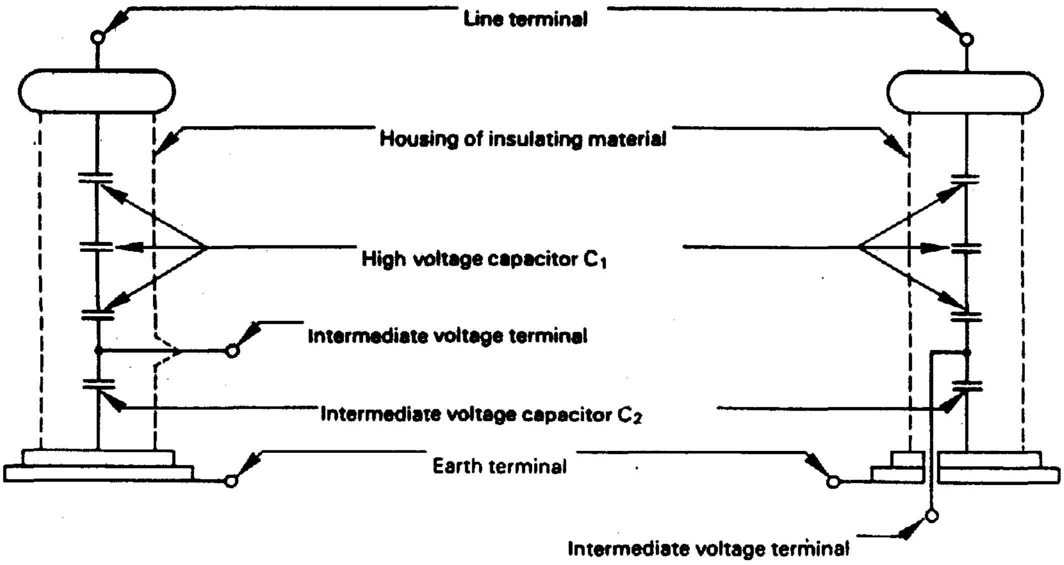

Line terminal
Housing of insulating material
High voltage capacitor C₁
Intermediate voltage terminal
Intermediate voltage capacitor C₂
Earth terminal
Intermediate voltage terminal

FIG. A3. - Capacitor divider (part of capacitor voltage transformer, not used for connection for power line carrier coupling).

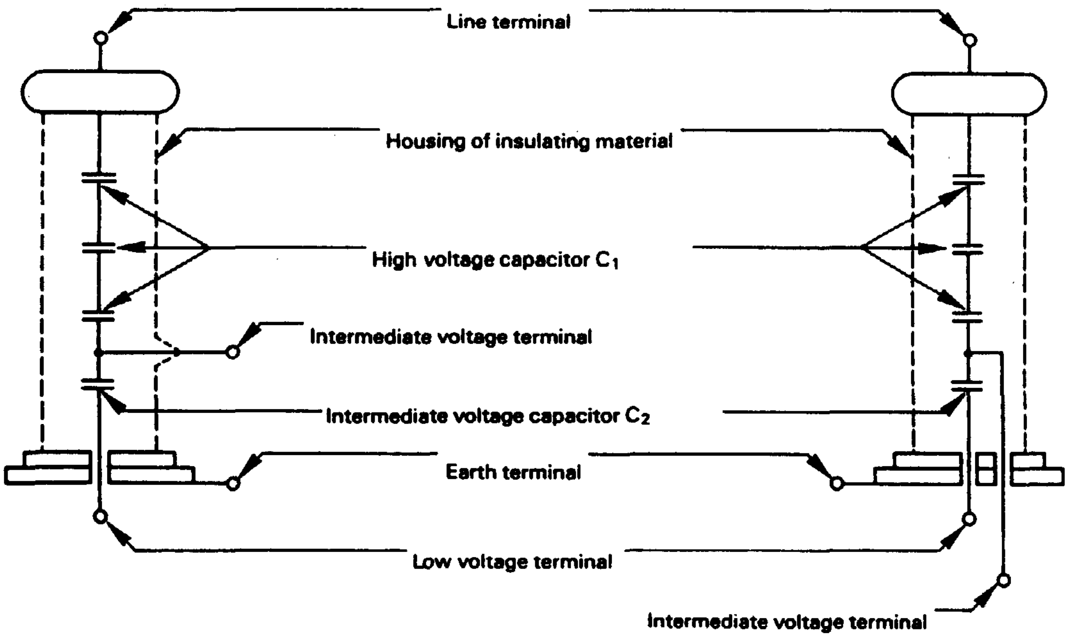

Line terminal
Housing of insulating material
High voltage capacitor C₁
Intermediate voltage terminal
Intermediate voltage capacitor C₂
Earth terminal
Low voltage terminal
Intermediate voltage terminal

FIG. A4. - Capacitor divider (part of capacitor voltage transformer, with connection for power line carrier coupling).

APPENDIX B

HIGH-FREQUENCY CHARACTERISTICS OF COUPLING CAPACITORS FOR POWER LINE CARRIER CIRCUITS

B1. High frequency capacitance and equivalent series resistance

The frequency conditions mentioned in Clause 1 are those occurring in the great majority of cases. For different conditions that may occur in certain countries for frequencies above 500 kHz or below 30 kHz, the recommendations may differ, if necessary, from the values in Section Two (Clause 12).

It may likewise prove necessary to lay down requirements deviating from the present recommendations, for instance by direct agreement between the manufacturer and purchaser, for other special conditions such as very low rated capacitance (below 2 000 pF) or high rated capacitance at very high rated voltage (above 420 kV) provided they are compatible with the requirements of good high frequency transmission.

The fact should be considered that any change in the high frequency characteristics of the coupling capacitor, as, for instance, a change in the capacitance of the coupling capacitor itself or the introduction of stray quantities (capacitance, etc.) may affect the transmission bandwidth (useful frequency band), shift this band and produce an additional coupling attenuation.

B2. Stray capacitance and conductance of the low voltage terminal

Stray capacitance and conductance of the low voltage terminal, with respect to the earth terminal, should be as low as possible.

Notes *1.*- Values higher than 20 µs may have an appreciable effect on the bandwidth of the coupling equipment, at least for operation at frequencies lower than 100 kHz and for a low coupling capacitance.

2.- The values given in Clause 12 cannot generally be obtained when testing a complete capacitor voltage transformer, owing to the capacitance and the additional losses of the electromagnetic unit. In the case of a capacitor voltage transformer, the following limiting values can generally be assumed:

- for stray capacitance: 300 + 0.05 C_N (in pF), where C_N represents the rated capacitance (in accordance with Sub-clause 3.5), expressed in picofarads;
- for stray conductance: 50 µs.

3.- Terminal design and arrangement should be chosen so that the effect of adverse atmospheric conditions (humidity, snow, frost, dust, etc.) does not involve stray capacitance and conductance values appreciably higher than those stated above and in Clause 12.

B3. *High frequency current of a coupling capacitor*

Coupling capacitors shall be designed to withstand a steady high frequency current through the coupling capacitor of at least 1 A (r.m.s. value of current equivalent to a power of 400 W for a terminal resistance of 400 Ω), without any damage or deterioration.

B4. Measurement of the high frequency capacitance and equivalent series resistance (Clause 12)

Measurements shall be made on the coupling capacitor stack.

Measurements to be made in a climatic chamber to check the effect of low temperature may be performed, by agreement, on a model capacitor containing a limited number of elements.

The measuring method giving the values of high-frequency capacitance and equivalent series resistance may be chosen, as convenient, from various high frequency procedures such as bridge methods, substitution methods, etc.

Figure B1 gives an example of a bridge measuring method, enabling the quantities required (C_s and R_s) to be read off directly.

After the bridge is balanced by adjusting C_m and R_m, the required quantities are given by:

$$C_s = C_m$$

$$R_s = R_m$$

When the measuring method used does not give series values, these can be computed from the parallel values C_p and R_p:

$$C_s = C_p\ [1 + 1/(\omega^2 \cdot C_p{}^2 \cdot R_p{}^2)]$$

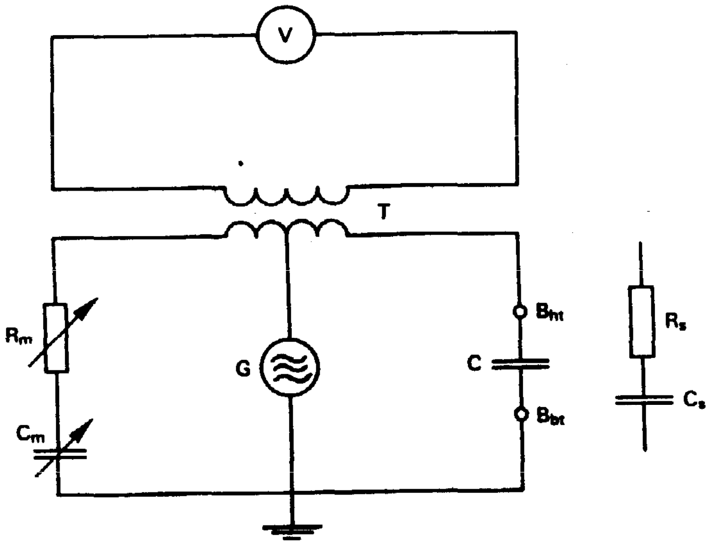
$$R_s = R_p/(1 + \omega^2 \cdot C_p{}^2 \cdot R_p{}^2)$$

It is recommended that capacitances and inductances due to the measurement connections should be reduced as far as possible (by minimizing the length thereof) and likewise the earth capacitances of the coupling capacitor. Particular care should be taken to screen the measuring equipment and, if necessary, the connections.

If the stray capacitance and inductance of the measuring arrangement produce an appreciable effect, this shall be allowed for in computing the results of the measurements.

The introduction of uncontrolled stray elements may give rise to serious errors in measuring the capacitance.

In order to reduce to insignificant values the inductances due to the measurement connections, it is suggested that two cages, insulated one from the other, and each made with six or eight copper straps are used. These cages shall surround the capacitor under test and shall be in close contact with the insulating material throughout its length. One end of the upper cage should be connected to the line terminal, while one end of the lower cage should be connected to the low voltage terminal. The measuring bridge should be connected with two wires as short as possible, to the two other ends of the cages as shown in Figure B2.



C = coupling capacitor under test

R_s = equivalent series resistance of the coupling capacitor

C_s = high frequency capacitance of the coupling capacitor

B_{bt} = low voltage terminal

B_{ht} = line terminal

C_m = variable measuring capacitor

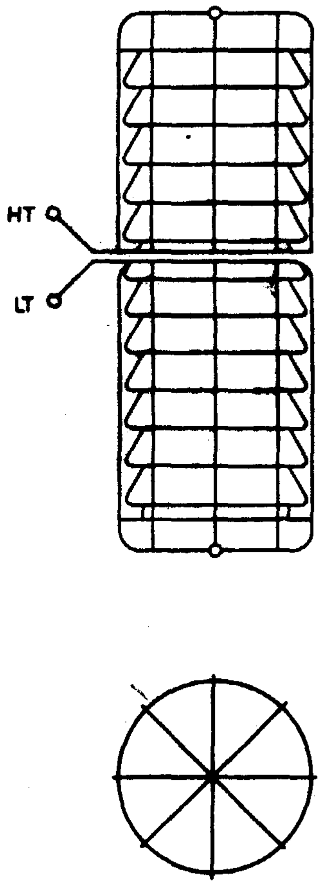
R_m = variable measuring resistor

G = high frequency generator

T = hybrid (differential) transformer

V = voltmeter or other signal detector

FIG. B1. - Bridge method for measuring the high frequency capacitance and equivalent series resistance of a coupling capacitor.



HT = Line terminal

LT = Low voltage terminal

FIG. B2. - Wiring diagram of the measuring circuit for the high frequency capacitance and equivalent series resistance of a coupling capacitor.

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 270 : 1981 Partial discharge measurements	IS 6209 : 1982	Equivalent
IEC 507 : 1975 Artificial pollution tests on high voltage insulators to be used on ac systems	IS 8704 : 1995	do
IEC 566 : 1982 Capacitors for use in tubular fluroscent and other discharge lamp circuits	IS 1569 : 1976	do
IEC 815 : 1986 Guide for the selection of insulators in respect of polluted conditions	IS 13134 : 1992	do
IEC 831 : 1991 Shunt power capacitors of the self healing type for ac power systems having a rated voltage up to and including 660 V	IS 13340 : 1993	do
IEC 871-2 : 1987 Shunt capacitors for ac power systems having a rated voltage above 660 V—Part 2 : Endurance testing	IS 13925 (Part 2) : 1994	Identical
IEC 931 : 1989 Shunt capacitors of the non-self healing type for ac power systems having a rated voltage up to and including 660 V.	IS 13585 (Part 1) : 1994	Equivalent

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards Monthly Additions'.

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